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Windsor Air Quality Study
L'étude sur la qualité de l'air de Windsor

Windsor Air Quality Committee

Comité sur la qualité de l'air de Windsor

Executive Summary

REPORTS OF THE WINDSOR AIR QUALITY STUDY

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WINDSOR AIR QUALITY STUDY:
EXECUTIVE SUMMARY REPORT

FALL 1994

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WINDSOR AIR QUALITY STUDY:
EXECUTIVE SUMMARY REPORT

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Windsor Air Quality Committee

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The results of the science module will be used by the multi-stakeholder Windsor Air Quality Committee (WAQC) to develop remedial measure recommendations. The WAQC has representation from Windsor residents (Ms. Donna Beausoleil, Mr. Timothy Carder, Ms. Susan Dufour, Mr. Chris Hudec, Ms. Bernadette Leclair, Ms. Helen Mader, Mr. Bruce Singbrush, Mr. Maciej Tomczak, Ms. Marcia Valiante, Ms. Helena Ventrella and Mr. Mike Walsh), citizens' groups (Citizen's Environmental Alliance - Mr. Rick Coronado, Sandwich Clean Air Committee - Ms. Leona Leveque, and Windsor Bicycling Committee - Mr. Mark Buckner), health agencies (American Lung Association of Michigan - Mr. Alex Sagady, Essex County Medical Society - Dr. Deborah Hellyer, The Lung Association - Brian Stocks, and Windsor - Essex Health Unit - Dr. G. A. Heimann), labour (Canadian Auto Workers Union - Mr. Rob Sheehan and Windsor District Labour Council - Mr. Pete Thomas), Industry (Chrysler Canada - Mr. Paul Hansen, Eco-Analytical Laboratory - Ms. Deborah Winsor, Ford Motor Company - Mr. Rick Martin, Hiram Walker Limited - Mr. Rick Aldi, and Zalev Brothers - Ms. Susan Sawyer-Beaulieu), education/research (Great Lakes Institute - Mr. Doug Haffner), government (City of Windsor Planning Department - Mr. Bob Hayes, City of Windsor Pollution Control - Mr. Lou Romano, Mr. Ron Drynan, Mr. Kit Woods, County of Essex - Mr. Joe Cimer, Environment Canada - Ms. Esther Bobet, Ontario Ministry of Environment and Energy - Mr. Jim Janse, Southeast Michigan Council of Governments - Mr. Chuck Hersey, and Wayne County Air Pollution Office - Mr. Rajendra Sinha). The able leadership of the Committee's chairperson, Mr. Jim Janse (and formerly, Mr. Doug MacTavish) and the commitment and dedication of the Committee's members are instrumental to the success of this Study.

Although the science component of the Windsor Air Quality Study was carried out under the leadership of the Ontario Ministry of Environment and Energy, a number of other agencies contributed:

- Environment Canada provided data from three ambient air monitoring stations in Windsor and Walpole Island, analyzed the carbonyl field samples of the personal exposure assessment program, as well as assisting with the compilation of the emissions inventory for the Windsor/Detroit airshed.

- Much of the emissions inventory work was carried out under contract by three consulting firms - CW Environmental Inc., Envirometrex, and Engineering Science, Inc..

- The production of the emissions inventory would not have been possible without the cooperation of local industries, too numerous to mention, and the Wayne County Air Pollution Control Division and Michigan Department of Natural Resources.

- These US agencies also provided ambient air monitoring data from the Detroit area. Roy F. Weston, Inc. made available monitoring data collected under contract to the Greater Detroit Resource Recovery Authority.

- The assistance of the Windsor-Essex Health Unit and the Windsor Lung Association was invaluable in carrying out the personal exposure assessment program.

Summary of Key Findings

The Ontario Ministry of Environment and Energy, in partnership with the Windsor Air Quality Committee, conducted an intensive airborne toxics study in the Windsor area. The ultimate aim of the Study was to decrease the exposure of Windsor residents to airborne toxic chemicals, involving the community in the decision-making process for their own airshed, in the most cost-effective way. The two integral components of this Study are: scientific investigative studies and remedial actions. The former component is led by the Ministry of Environment and Energy whereas the Windsor Air Quality Committee (a local, multi-stakeholders group) has the mandate of recommending cost-effective remedial measures.

The majority of the field investigations were carried out during the period of June 1991 through March 1993. In this report, key results of the scientific module are summarized. For a less technical explanation of findings, see the "Plain Language Summary" report. These results will form the basis for the Windsor Air Quality Committee to develop recommendations for action.

The scientific effort comprised data collection (emissions, ambient air monitoring, personal exposure, soil and crop produce) and the use of certain scientific tools (mathematical modelling and risk analysis) to characterize the airborne toxics situation in Windsor. Mathematical model based source apportionments and health effects assessments were carried out, utilizing the emissions and monitoring data collected along with health risk information.

Of primary interest are three questions: (1) What are the air pollutants of concern in Windsor? (2) What is the risk due to exposure to these chemicals? and (3) Where and how much of these pollutants are emitted?

From the original target list, ten compounds were selected for in-depth modelling and health effects investigation in the Windsor Air Quality Study. They are in four categories: metals (cadmium, chromium (VI), and mercury); volatile organic compounds (VOCs -benzene, 1,3-butadiene, carbon tetrachloride, 1,4-dichlorobenzene, and formaldehyde); polynuclear aromatic hydrocarbons (PAHs, including benzo(a)pyrene); and semi-volatile organic compounds (SVOCs - specifically dioxins and furans). Although the following key findings cover these ten compounds, they focus on six pollutants which have been assessed to have higher potential risks in Windsor and for which meaningful source apportionments could be done. Information on the contributing sources to the air concentration levels of these six pollutants in Windsor has been summarized in a table at the end of this summary.

Pollutants of Concern

- Outdoor environments:

  -Using the calculated estimates of potential cancer risk from long term inhalation of outdoor air in Windsor, the following pollutants are of concern: chromium (VI), benzene, 1,3-butadiene, polynuclear aromatic hydrocarbons[1] (PAHs which include benzo(a)pyrene (B(a)P)), carbon tetrachloride, cadmium, and 1,4-dichlorobenzene[2].

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[1] Source apportionment addressed B(a)P only, since only B(a)P emissions were available. The health effects assessment addressed the spectrum of risks ranging from B(a)P to "carcinogenic PAHs". The source apportionment, based on B(a)P is assumed to apply to all PAHs.

-The air pollutants which may contribute to long term non-cancer health effects are: formaldehyde, chromium (VI), and cadmium.

- Indoor environments:

  -Based on calculated estimates of cancer risks from non-smokers, the following are the contaminants of concern in indoor air: 1,3-butadiene, benzene, chromium (VI), carbon tetrachloride, PAHs, formaldehyde, cadmium, and 1,4-dichlorobenzene.

  -The contaminants which may pose non-cancer risks for non-smokers are: formaldehyde, carbon tetrachloride, 1,3-butadiene, and chromium (VI).

- Smoking activity:

  -Smoking greatly increases a smoker's intake of benzene, 1,3-butadiene, formaldehyde, cadmium, chromium, PAHs, and dioxins and furans.

Risks

- Risks from direct outdoor air exposure are appreciably less than those from indoor air exposure.

- Smoking (including secondhand smoke) and emissions from household/office materials contribute significantly to the risk for indoor environments.

- In general, inhalation is a more significant pathway in terms of contributing to health risks than the ingestion and dermal pathways for the target compounds investigated during this Study.

- Ingestion was identified as a major route of exposure (in terms of magnitude of intake but not contribution to health risks) for formaldehyde, cadmium, chromium(VI), dioxins and furans, and mercury. Marginally, polynuclear aromatic hydrocarbons may contribute to health risks via the ingestion route.

- Exposure through inhalation is far more significant for 1,3-butadiene than through ingestion and dermal absorption.

- Limited analysis indicated that ingestion and dermal contribution to carcinogenic and non-carcinogenic risk is insignificant for benzene, cadmium, chromium, and formaldehyde.

- Based on existing monitoring information for dioxins and furans, the sum of exposures from all routes is less than 25% of the tolerable daily intake, therefore the possibility of long-term health effects in Windsor due to these compounds is unlikely. In the case of mercury, inhalation and ingestion exposures amount to, respectively, less than 10% and about 50%, of the applicable chronic acceptable exposure guidelines, suggesting that the possibility of long-term health risks in Windsor due to mercury is unlikely. However, because of their persistence in the environment and bioaccumulation in the food chain, efforts should continue to reduce emissions of and human exposures to these substances.

---

[2] Classification of 1,4-dichlorobenzene as a carcinogen has recently been removed from the Integrated Risk Information System (IRIS) database by the US EPA, hence the calculated cancer risks may bear no significance. Also because no emissions information was available for Detroit, source apportionments were not possible for this compound.

- The range of additive risks (calculated by adding the risks for each compound) from all pollutants associated with outdoor air quality is between 5 x 10^{-5} and 9.4 x 10^{-4} and is not appreciably different from those found in other US urban areas where similar evaluations were conducted (9 x 10^{-5} and 5 x 10^{-3}). No Canadian urban airshed studies are available for this comparison.

Sources of Pollutants

- Windsor's air pollutant emissions range from 82 g/yr for dioxins to 140 thousand kg/yr for benzene. Of the pollutants included in the inventory study, about 74% of Windsor's emissions are from area sources (e.g., traffic, residential/commercial fuel combustion, and small industrial operations).

- Detroit and surrounding sources contribute about 58% for cadmium, 65% for chromium, 67% for benzo(a)pyrene, 67% for benzene, and 76% for 1,3-butadiene.

- Area sources, particularly vehicular and fuel combustion sources, in Windsor and Detroit, dominate the contribution to ground level concentrations of benzene (84%), 1,3-butadiene (96%), and benzo(a)pyrene (99%) in Windsor.

- Benzo(a)pyrene, the only compound measured in Windsor that exceeds the existing Ontario's Ontario air quality criterion, has about 67% of its ground level concentration contributed from US sources. The remainder from Windsor and vicinity originate from vehicles (12%) and wood burning stoves (21%).

- Point sources dominate (i.e., 50% from the steel industry in Detroit and 16% from the automobile manufacturing sector in Windsor) the contribution to ground level concentrations of chromium in Windsor.

- Road dust from Windsor and Detroit, the motor vehicle manufacturing sector in Windsor, and the steel industry in Detroit contribute 35%, 27%, and 13%, respectively to the cadmium air concentrations in the Windsor area.

- Photochemical reactions and long range transport of air pollutants are responsible for most of the ground level formaldehyde in Windsor.

- Carbon tetrachloride was found to originate primarily from long range transport.

- Benzo(a)pyrene levels in ambient air were higher prior to the intensive monitoring period of the Study. The coke ovens in the Detroit area were shut down for most of the Study period. Dispersion modelling indicated very minimal contribution to ambient levels of B(a)P in Windsor from the retrofitted coke ovens in Detroit which resumed operation in late 1992. There were insufficient air monitoring results available to confirm the modelling results on the impact of the resumed coke oven operations.

- Northwest Windsor has the highest concentrations of 1,3-butadiene and benzo(a)pyrene and north-central Windsor has the highest concentrations of benzene, chromium, and cadmium, reflecting local source contributions, primarily from the automobile manufacturing sector.

The following table lists six pollutants of higher cancer and non-cancer health risks in Windsor. The table also summarizes the relative contributions from different sources to the ambient concentration levels of these chemicals in Windsor.

CHEMICALS OF HEALTH CONCERN IN WINDSOR: PERCENT CONTRIBUTION TO AIR CONCENTRATIONS FROM VARIOUS SOURCES[*]

	Cd	Cr	B(a)P	C_6H_6	C_4H_6	CH_20[**]
FROM WINDSOR SOURCES						
Motor vehicle manufacturing	27	16	-	8	-	-
Steel mills and iron foundries	-	1	-	-	-	-
Mobile sources	-	2	12	17	16	7
Utilities and other fuel combustion	-	7	21	3	-	1
Other point sources	2	9	-	2	-	-
Other area sources	13	-	-	3	8	-
FROM DETROIT SOURCES						
Motor vehicle manufacturing	3	1	-	1	1	-
Steel mills and coke ovens	13	50	-	2	-	-
Mobile sources	-	-	44	31	45	7
Utilities and other fuel combustion	-	3	22	6	-	-
Other point sources	6	10	1	3	3	7
Other area sources	36	1	-	24	27	3
Total %	100	100	100	100	100	25

---

[*] Cd = cadmium; Cr = chromium; B(a)P = benzo(a)pyrene; C_6H_6 = benzene; C_4H_6 = 1,3-butadiene; CH_2O = formaldehyde

[**] Photochemical reactions and long range transport of air pollutants are responsible for most of the ground level formaldehyde in Windsor, resulting in only a 25% contribution from the definitive sources in Windsor and Detroit.

1. Study Objectives and Description

1.1 *Background: Why Windsor?*

The concept of investigative urban airshed studies in Ontario to characterize chronic toxic pollutants emerged in the late 1980s. There was a growing concern in the province over the health impacts of airborne toxics, notably particulate-borne trace metals and volatile and semi-volatile organic compounds. These persistent, hazardous substances potentially produce a broad spectrum of undesirable health effects during prolonged exposure. Many of these substances are known or suspected carcinogens.

Information from toxics assessment programs such as the US National Toxic Release Inventory fuelled this concern. This study indicated that more than a million tons of toxic substances were escaping to the atmosphere in the US every year. The urban toxics monitoring program in the United States has been underway since the mid-1980s, and has found a wide variety of known and suspected carcinogens in urban environments. Risk assessment analyses for airborne toxics had been carried out in many American cities which were similar in size and industrial nature to Ontario urban communities.

Windsor's air quality had been documented as far back as the 1940s. Routine monitoring for various air pollutants in the Windsor airshed such as suspended particulate matter, sulphur dioxide, carbon monoxide and ozone has been ongoing for more than two decades. Local apprehension over airborne toxics intensified in late 1986 with the construction of the Greater Detroit Resource Recovery Authority (GDRRA) municipal waste incinerator in Detroit. The GDRRA incinerator was expected to be a significant source of mercury and chlorinated dibenzo- dioxins and dibenzo-furans (dioxins and furans) emissions. Furthermore, a number of risk assessment studies in the United States had identified steel mills as being an especially significant emissions source of airborne toxics. Since the City of Windsor is located in the prevailing downwind direction of Detroit-based steel mills and the GDRRA incinerator, the cause for concern is magnified.

In December of 1990, the International Joint Commission's Air Quality Advisory Board on the Detroit/Windsor - Port Huron/Sarnia Corridor published a report which concluded that there was sufficient information to indicate a significant public health issue in the airshed, requiring additional abatement and remedial measures. The report also recommended that a comprehensive air toxics monitoring program should be developed and implemented in the region; that the existing emission inventory data base be upgraded; and that regulatory decisions should take into consideration the implications of other exposure pathways in addition to air, such as food and water.

In order to address the air quality issues, the Ontario Ministry of Environment and Energy (MOEE) embarked on an intensive airborne toxics study in Windsor. The ultimate aim of the Study is to decrease the exposure of Windsor residents to airborne toxic chemicals, involving the community in the decision-making process for their own airshed.

1.2 Objectives

The Windsor Air Quality Study was designed to answer the following questions:

- What are the airborne toxics which might cause concern?
- What are the levels of airborne toxics in the airshed?
- What are the major contributing sources for the chemicals of concern?
- What are the most significant exposure pathways for the chemicals of concern?
- What are the relative health risks of Windsor citizens resulting from exposure to the airborne toxics?

The majority of the field investigations designed to answer the above questions were carried out during the period June 1991 through March 1993. These investigations included a detailed compilation of pollutant emission rates in the Windsor/Detroit airshed, an intensified monitoring program, and data analysis using mathematical models and health effects information. The results of this Study will be provided to the community through their involvement on the Windsor Air Quality Committee in order to recommend cost-effective approaches for remedial measures.

The focus of the Windsor Air Quality Study was on substances which pose high risks and contribute to chronic health effects. A broad spectrum of pollutants was identified for the Windsor Air Quality Study initially using information on chronic toxicity, a review of findings from other investigations and information available for pollutants in the Windsor airshed. During the study, additional information on air pollutants and emissions became available and the list of target pollutants was revised to reflect this additional information.

Ten substances were targeted for in-depth modelling and health effects investigation in the Windsor Study because of their potential for health risk, bioaccumulation, persistence, and toxicity. They are listed in Table 1.2.1. Entries for these substances are shaded in the tables presented in later sections of this report. Other chemicals of secondary consideration were measured and are described in the respective Study component reports. Pollutants which cause acute effects, such as ozone, sulphur dioxide, or carbon monoxide, were not addressed in this Study. These are the subject of other Ministry programs and are reported regularly in the Ministry's daily Air Quality Index as well as the Annual Air Quality in Ontario Report. Further information may be obtained from the Public Information Centre, Ministry of Environment and Energy, 135 St. Clair Avenue West, Toronto, Ontario M4V 1P5 (416-323-4321).

Table 1.2.1: Windsor Air Quality Study: Chemicals Targeted for In-Depth Modelling and Health Effects Investigation

Chemical Group	Substance
Metals	Cadmium Chromium (VI) Mercury
Volatile Organic Compounds (VOCs)	Benzene 1,3-Butadiene Carbon tetrachloride 1,4-Dichlorobenzene Formaldehyde
Polynuclear Aromatic Hydrocarbons (PAHs)	Benzo(a)pyrene
Semi-Volatile Organic Compounds (SVOCs)	Dioxins Furans

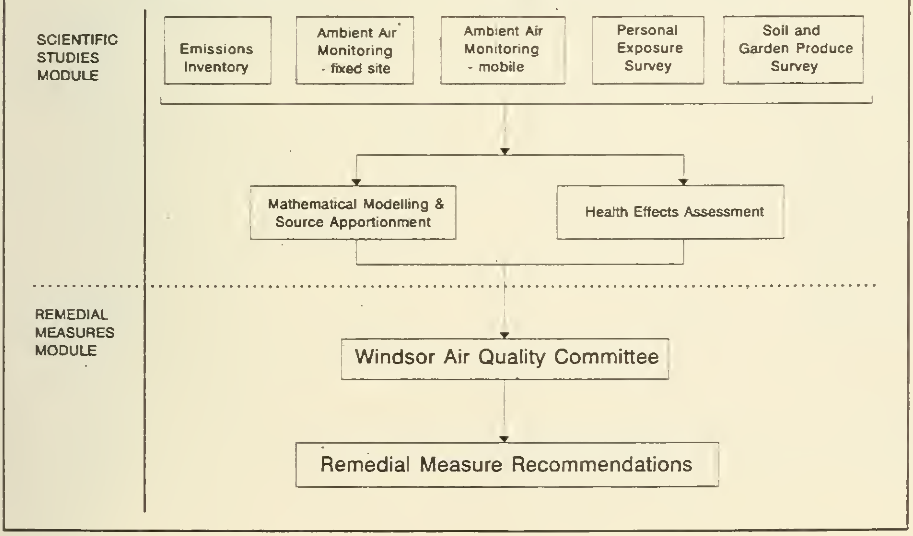
2. Framework of Study

The Windsor Air Quality Study places equal emphasis on the understanding of the airborne toxic pollutants problem in the Windsor area and the development of an abatement strategy to remedy the situation. Figure 2.1 shows the components and the linkage between the scientific studies module and the remedial measures module.

The first module consists of a series of investigative studies led by the Ministry of Environment and Energy. This scientific module has seven components: (1) emissions inventory; (2) fixed site ambient air monitoring; (3) mobile air monitoring; (4) personal exposure measurements; (5) soil and garden produce survey; (6) mathematical modelling; and (7) health effects assessment. Emissions and ambient monitoring data are input for the modelling exercise to identify and apportion source contributions to Windsor's pollution levels. Health risk assessment takes into account ambient monitoring data, personal exposure data, soil and vegetation data and information on toxicology and potential hazards to identify chemicals and pathways which pose potential risks to Windsor residents upon exposure.

The second module will be the recommended remedial measures by the Windsor Air Quality Committee. The Committee is a multi-stakeholder forum with representation from governments (the Ministry, Environment Canada, and the City of Windsor), the Windsor-Essex Health Unit, local environmental interest groups and industry, academia, and the

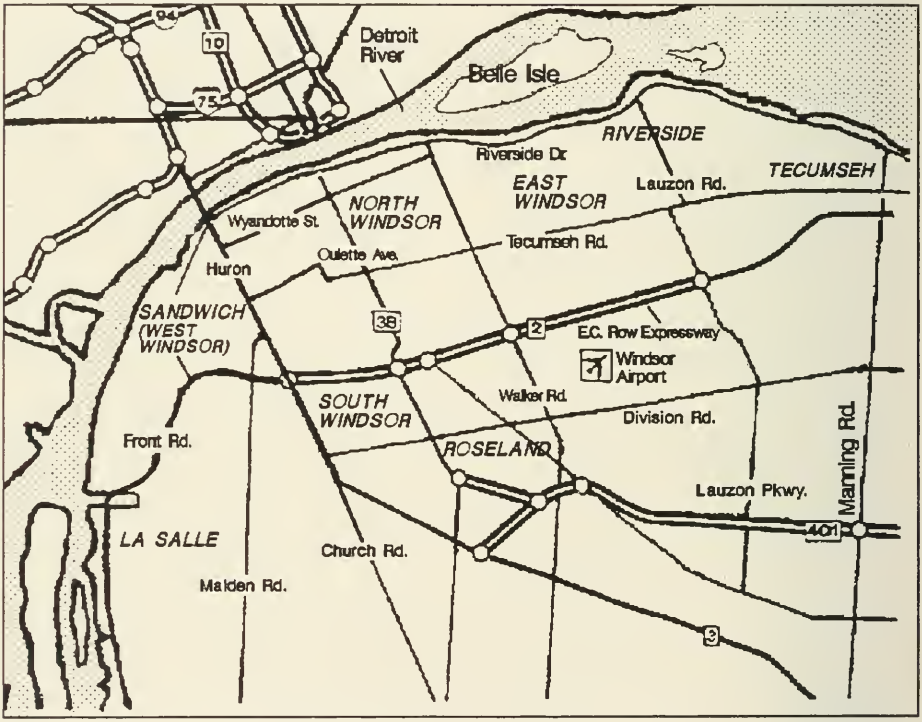
FIGURE 2.1
FRAMEWORK OF WINDSOR AIR QUALITY STUDY


SCIENTIFIC STUDIES MODULE
Emissions Inventory
Ambient Air Monitoring - fixed site
Ambient Air Monitoring - mobile
Personal Exposure Survey
Soil and Garden Produce Survey
Mathematical Modelling & Source Apportionment
Health Effects Assessment
REMEDIAL MEASURES MODULE
Windsor Air Quality Committee
Remedial Measure Recommendations

Southeast Michigan Council of Governments. Task groups have been set up to address (1) transboundary pollution; (2) point sources - regulatory controls; (3) point sources - voluntary controls; (4) transportation; and (5) communications and public education.

The Committee will use information provided by these scientific investigations to recommend strategies for cost effective remedial measures to reduce risks due to airborne toxic pollution in the Windsor area. Neighbourhood areas in Windsor are shown in Figure 2.2.

Figure 2.2 Neighbourhood areas in Windsor



Neighbourhood names for Windsor were taken from a MapArt Windsor City Plan, Copyright 1988 MapArt Corporation. The area here labelled as "North Windsor" includes the neighbourhoods of Walkerville, Central Windsor, and South Central Windsor. The neighbourhood of Sandwich has generally been referred to as "West Windsor" throughout the Windsor Air Quality Study reports.

3. Study Components and Result Summaries

3.1 *Emission Inventory*

A comprehensive inventory of emissions of airborne toxics was carried out for the Windsor/Detroit airshed, using accepted air toxics emission inventory methodologies of Environment Canada and the US EPA.

Emissions from point sources (i.e., major industrial sources) and area sources (e.g., traffic, residential/commercial fuel combustion, and small industrial operations) were compiled for the Ontario/Michigan Transboundary region covering an area approximately thirteen thousand square kilometres. This is a region of concentrated industrial activities and high population density. On the Ontario side of this studied region, an emission inventory from three counties (Essex, Kent and Lambton) was compiled. Sources compiled from the Michigan Detroit/Port Huron region comprised of seven counties (Lapeer, St. Clair, Oakland, Macomb, Washtenaw, Wayne and Monroe).

Over the greater Windsor area, a detailed emission inventory for point sources, area and mobile sources was compiled on one km by one km grid cells. Approximately seventy major point sources were characterized through a source quantification survey and subsequent verification of the MOEE estimated air toxics emissions with the reported industries.

The Detroit, US Transboundary emission inventory was compiled from data available from the US EPA and Michigan Department of Natural Resources. The data in this inventory were based on 1985 source information with updates introduced in the subsequent years up to 1991. There were 202 facilities with approximately 2,000 point source releases and approximately 350 area source grids of mixed sizes. The Detroit inventory has been assumed to approximate that of Wayne County.

A detailed presentation of the emission data and source information can be found in the Report **Windsor Air Quality Study: Emission Inventory for the Windsor/Detroit Airshed.**

Tables 3.1.1 and 3.1.2 provide the annual emission rates of selected air pollutants from Windsor and its vicinity (hereafter referred to as Windsor) and Detroit area (hereafter referred to as Detroit). Table 3.1.1 is based on data available for 1990, the year for which the industrial data were requested. Table 3.1.2 includes data from a variety of US data bases (1985-1991). For each substance, the emissions have been grouped under various broad sector categories:

- motor vehicle manufacturing (Ford, Chrysler and General Motors Plants on both sides of the border);
- steel mill and coke oven or iron foundry operations (Great Lakes Steel, etc., on the Detroit side only, since there are no steel mills in Windsor);
- mobile sources (e.g., cars, trucks, airplanes, boats, etc.);
- public or private utilities (power generating stations only);

- other industrial and area sources not covered by the above categories (e.g., home heating, miscellaneous industries, etc.).

The following points should be borne in mind:

- Air pollutant emissions from heavy industries such as steel mills, petroleum refineries and electric utilities are confined to Wayne County and its surrounding counties. Such industries are not found in Windsor.

- Chromium emissions are expressed as total chromium, not the Cr(VI) species which is considered to be the most toxic form and is the target compound of interest[1].

- Polynuclear aromatic hydrocarbons (PAHs) were originally compiled for the Windsor Study. However, benzo(a)pyrene (B(a)P) was subsequently estimated for the purposes of the modelling source apportionment since total PAHs emissions were not available for US sources.

- Emissions data for 1,4-dichlorobenzene, a target substance, is available for Windsor sources but not Detroit sources.

- Road dust, a significant source of cadmium, was not included as a fraction of the Detroit-side area source emissions whereas it was included in Windsor area source emissions.

- The Detroit-side area sources component excluded woodstove contributions of dioxins and furans while Windsor area source emissions included this fraction.

- There were no coke oven emissions in the Detroit area during the Study period, since the ovens were not operating due to process changes and plant closures. This is not a typical situation, and, normally, an atmospheric burden of various compounds from coke oven emissions (benzene, benzo(a)pyrene, trace metals) would be expected. In late 1992 a modernized coke oven battery was commissioned.

The total emission rate in kilograms per year (kg/yr) for each compound inventoried in Windsor and Detroit is given in Table 3.1.1 and 3.1.2. The final column indicates the percentage contribution of Windsor or Detroit emissions to the total Windsor/Detroit airshed load.

- Air pollutant emissions from the Windsor area are far less than those from the Detroit area. Windsor's contribution to the combined emissions of Detroit and Windsor range from 0.1% for vinyl chloride to 35.4% for chloroform. This is attributed to Detroit having a much larger industrial base, population and mobile source emissions.

- Windsor's air pollutant emissions range from 82 g/yr for dioxins to 140,000 kg/yr for benzene.

- About 74% of the studied pollutant emissions in Windsor are from area sources.

- Mobile sources are the main source of VOCs. Degreasing operations, dry cleaning

[1] In this Study, it was assumed in the modelling and health effects assessment work that Cr(VI) constitutes 20% of the total chromium loading, which is in agreement with a number of published investigations as well as some limited air sampling work in the Windsor airshed.

and consumer product usage are the largest emitters of chlorinated solvents.

- The main sources of heavy metal emissions include fuel combustion, mobile sources and iron foundry/automotive casting operations. An estimated 26,000 kg/yr of chromium were emitted from the Detroit area as compared to 1,400 kg/yr from the Windsor area.

- As much as 3,611,000 kg/yr of benzene were emitted from the Detroit area, mainly from mobile sources and industrial activities. The benzene emissions from the Windsor area only contributed 140,000 kg/yr to the studied airshed.

- Emissions of formaldehyde, primarily originating from transportation, were estimated to be 1,732,000 kg/yr from the Detroit area while only 75,000 kg/yr were emitted in the Windsor area. It should be noted that formaldehyde is primarily a secondary by-product of photochemical reactions and long range transport from areas outside the Study domain.

Table 3.1.1: Summary of 1990 emissions from point, area and mobile sources from Windsor and vicinity

Chemical Group	Substance	Emissions (kg/yr)							
		Motor Vehicle Manufacturing	Steel Mill Iron foundry	Mobile Sources	Public Utilities	Other Point Sources	Other Area Sources	Total Windsor Emissions	Percentage of Airshed Emissions
Metals	Arsenic	220	4	--	--	15	1,209	1,448	15.83
	Beryllium	--	--	--	--	9	--	9	2.35
	Cadmium	174	2	--	--	23	305	504	11.19
	Chromium (total)	602	12	53	--	434	340	1,441	5.25
	Lead	3,054	124	5,524	--	993	2,216	11,911	8.45
	Mercury	1	--	8	--	95	--	104	6.87
	Nickel	1,083	24	24	--	272	1773	3,176	13.70
VOC	Acrylonitrile	1,690	--	--	--	--	--	1,690	8.17
	Benzene	51,164	906	52,310	--	7,661	27,160	139,201	3.71
	1,3-Butadiene	7	--	16,419	--	--	17,898	34,324	1.96
	Carbon tetrachloride	--	--	--	--	2,591	64	2,655	17.64
	1,4-dichlorobenzene	--	--	--	--	--	12,447	12,447	
	Chloroform	--	--	--	--	2,850	112	2,962	35.42
	Ethylene dibromide	82	--	--	--	45	--	127	0.63
	Formaldehyde	1,943	24	48,220	--	4,079	20,263	74,529	4.13
	Methylene chloride*	14	--	--	--	605	51,784	52,403	26.68
	Perchloroethylene	208	--	--	--	41,121	74,887	116,216	7.80
	Trichloroethylene	--	--	--	--	--	10,025	10,025	1.30
	Vinyl chloride	--	--	--	--	--	43	43	0.09
PAH	Benzo(a)pyrene	--	--	8.23	--	0.003	48.13	56	1.66
SVOC**	Dioxins	--	--	--	--	0.000634	0.081	0.08	2.60
	Furans	--	--	--	--	0.001073	0,137	0.14	4.46
	Polychlorinated biphenyls	--	--	--	--	0.000253	0.246	0.25	0.12

NOTES:

- * Methylene chloride is not considered as VOC by the US EPA and Environment Canada
- ** SVOC = Semi-volatile organic compounds
- -- denoted either insignificant value or no emission sources detected

Table 3.1.2: Summary of emissions from point, area and mobile sources in Detroit Area (1985-1991 databases)

Chemical Group	Substance	Emissions (kg/yr)							
		Motor Vehicle Manufacturing	Steel Mills Coke Ovens	Mobile Sources	Utilities	Other Point Sources	Other Area Sources	Total Detroit Emissions	Percentage of Airshed Emissions
Metals	Arsenic	1,706	1,411	--	437	3,446	700	7,700	84.17
	Beryllium	45	--	--	--	329	--	374	97.65
	Cadmium	474	1,328	--	40	758	1,400	4,000	88.81
	Chromium (total)	684	22,771	25	436	1,109	975	26,000	94.75
	Lead	2,513	28,627	1,982	334	5,526	90,018	129,000	91.55
	Mercury	12	--	--	--	1,098	300	1,410	93.13
	Nickel	2,646	5,293	--	462	5,599	6,000	20,000	86.30
VOC	Acrylonitrile	--	16,790	--	--	2,210	--	19,000	91.83
	Benzene	13,623	42,551	2,003,083	313	86,513	1,464,917	3,611,000	96.29
	1,3-Butadiene	2,366	--	1,222,893	13	3,621	486,107	1,715,000	98.04
	Carbon tetrachloride	1,072	--	--	--	1,928	9,400	12,400	82.36
	Chloroform	1,390	--	--	--	2,610	1,400	5,400	64.58
	Ethylene dibromide	--	--	--	--	--	20,000	20,000	99.37
	Formaldehyde	1,408	7,423	652,158	6,985	746,184	317,842	1,732,000	95.87
	Methylene chloride*	5,000	3,347	--	--	16,653	119,000	144,000	73.32
	Perchloroethylene	7,004	6,035	--	--	21961	1,338,000	1,373,000	92.20
	Trichloroethylene	47,567	17,201	--	--	85,232	612,000	762,000	98.70
	Vinyl chloride	--	--	--	--	--	50,000	50,000	99.91
PAH	Benzo(a)pyrene	--	4	2,361	--	44	939	3,348	98.34
SVOC**	Dioxins	--	--	--	--	3	--	3	97.40
	Furans	--	--	--	--	3	--	3	95.54
	Polychlorinated biphenyls	32	--	--	--	168	--	200	99.88

NOTES:

* Methylene chloride is not considered as VOC by the US EPA and Environment Canada

** SVOC = Semi-volatile organic compounds

-- denoted either insignificant value or no emission sources detected

Detroit Inventory assumed to approximate that of Wayne County.

3.2 Ambient Air Monitoring

The objective of this component of the Study was to collate air quality data collected in the Windsor/Detroit area for use in mathematical source apportionment and health risk analysis.

Routine air monitoring was instituted at a downtown Windsor site in 1987 by Environment Canada, Conservation & Protection (ECC&P), in cooperation with the MOEE, for a number of airborne volatile and semi-volatile organic substances and trace metals. The monitoring activity was expanded in 1990, and again during the period of June 1991 to March 1993. In this Study, the Windsor measurements were supplemented by Detroit area data obtained from the Wayne County Air Pollution Control Division, the Michigan Department of Natural Resources and Roy F. Weston, Inc. Figure 3.2.1 shows the locations of the monitoring stations.

In addition to most of the target substances, ambient air samples were analyzed for many other toxics. A detailed description of the ambient air toxics monitoring method and results are presented in the companion report, **Windsor Air Quality Study: Ambient Air Monitoring Activities**.

Table 3.2.1 summarizes the results of the ambient air monitoring program for airborne toxics at the five Windsor stations together with Ontario's air quality criteria, when applicable.

The measurements for all of the stations are pooled to give a picture of the overall airshed ambient levels rather than a spatial distribution across the city. For a more representative understanding of long-term air quality in the airshed, all data are included, from the inception of monitoring at each station to the end of 1992 (if available). Thus, the period of time covered may vary from one pollutant to another and the monitoring coverage represented is not limited to the designated Windsor Air Quality Study sampling period. For all the compounds except dioxins and furans, the statistics are based on 24 hour samples. For dioxins and furans, 24 and 48 hour samples were used to compute annual values.

Even though air samples were analyzed for several polynuclear aromatic hydrocarbons (PAHs), benzo(a)pyrene (B(a)P) is the only PAH compound with individual results shown. Measured concentrations of the other PAHs can be found in the Ambient **Air Monitoring Activities** report.

- The observed mean and maximum concentration levels of some of the pollutants selected for primary investigation are: 0.0016 and 0.091 ug/m^3 for cadmium; 0.006 and 0.14 ug/m^3 for chromium; 2.64 and 11.65 ug/m^3 for benzene; 0.19 and 1.38 ug/m^3 for 1,3-butadiene; 0.74 and 8.50 ug/m^3 for carbon tetrachloride; 0.89 and 14.60 ug/m^3 for 1,4-dichlorobenzene; 3.70 and 25.06 ug/m^3 for formaldehyde; and 0.51 and 15.29 ng/m^3 for benzo(a)pyrene.

- In general, the mean concentration levels for the pollutants monitored are considerably lower than applicable Ministry air quality criteria. Maximum measured values are also below these criteria. The exception is benzo(a)pyrene. For this compound, the long-term average (0.51 ng/m^3) for the Windsor area exceeds the existing annual criterion (0.3 ng/m^3), and the maximum concentration (15.29 ng/m^3) observed at a specific monitoring site exceeded the 24 h criterion of 1.1 ng/m^3 (for a single source).

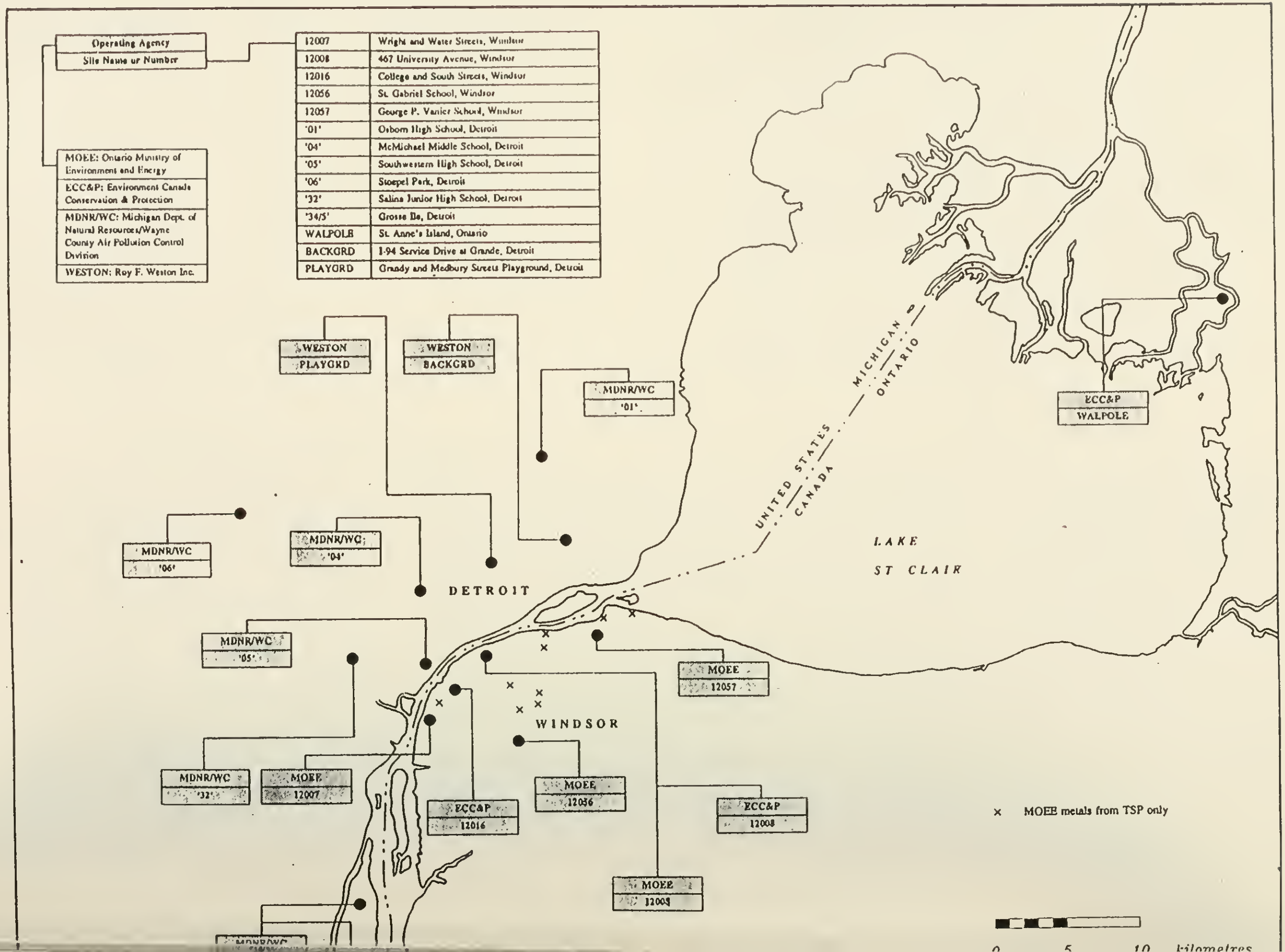
- Dioxin and furan levels also seem to be higher in Windsor than other Ontario cities, and are possibly due to the presence of the Greater Detroit Resource Recovery Authority incinerator. A large sewage sludge incinerator in Detroit may also contribute to dioxin levels, although they were not included in the emissions inventory or modelled. Elevated levels of formaldehyde were observed at site 12016 in West Windsor.

A comparison of ambient concentrations measured in Windsor with those measured in other Ontario and Canadian communities of some selected substances is shown in Figure 3.2.2. Since measurements are shown for the individual Windsor stations, a comparison is also possible for the west Windsor stations (12007 and 12016) with data from other areas of Windsor, where available. West Windsor has been identified as an area where air quality problems may be more severe than elsewhere in the airshed, and there are reports of frequent odour episodes. A range of annual average concentrations, where several years' data were available, is shown for each station. Hamilton sites are identified as follows: Mtn (Mountain), DnTn (Downtown) and Beach (Beach Boulevard).

Figures for cadmium and chromium are based on data from inhalable particulate monitors operated by the federal government. Only federal government data were used so that the comparison with other monitoring sites in Canada would be consistent with respect to sampling and analytical methodology. For the metals data, Vancouver 1 is Rocky Point Park and Vancouver 2 is West 10th Avenue. Montreal 1 is at 1125 Ontario Street and Montreal 2 is at Duncan and Décarie.

- Target substance concentration ranges in Windsor are, in general, comparable to or lower than those found in other Ontario communities. One exception is benzo(a)pyrene, where concentration levels at the west Windsor site (12007) seem to be considerably higher. Site 12007 is immediately opposite and usually downwind of Zug Island, Detroit. This area is heavily industrialized and includes two steel mills. The higher levels of B(a)P were obtained prior to the Study period and the shutdown of the coke ovens. During most of the Study period, the Detroit area coke ovens were not operating. One coke oven was re-commissioned late in 1992. Its impact was estimated in the **Windsor Air Quality Study: Mathematical Modelling/Source Apportionment.**

Figure 3.2.1: Ambient air toxics monitoring stations in the Windsor and Detroit area


Operating Agency
Site Name or Number
MOEE: Ontario Ministry of Environment and Energy
ECC&P: Environment Canada Conservation & Protection
MDNR/WC: Michigan Dept. of Natural Resources/Wayne County Air Pollution Control Division
WESTON: Roy F. Weston Inc.
12007 Wright and Water Streets, Windsor
12008 467 University Avenue, Windsor
12016 College and South Streets, Windsor
12056 St. Gabriel School, Windsor
12057 George P. Vanier School, Windsor
'01' Osborn High School, Detroit
'04' McMichael Middle School, Detroit
'05' Southwestern High School, Detroit
'06' Stoepel Park, Detroit
'32' Salina Junior High School, Detroit
'34/5' Grosse Ile, Detroit
WALPOLE St. Anne's Island, Ontario
BACKGRD I-94 Service Drive at Grande, Detroit
PLAYGRD Grandy and Medbury Streets Playground, Detroit
WESTON PLAYGRD
WESTON BACKGRD
MDNR/WC '01'
MDNR/WC '06'
MDNR/WC '04'
MDNR/WC '05'
MDNR/WC '32'
MOEE 12007
ECC&P 12016
MOEE 12056
MOEE 12057
ECC&P 12008
MOEE 12008
ECC&P WALPOLE
DETROIT
WINDSOR
LAKE ST CLAIR
MICHIGAN
ONTARIO
UNITED STATES
CANADA
× MOEE metals from TSP only
0 5 10 kilometres

able 3.2.1: Summary of ambient air results from the Windsor monitoring sites

Substance	Units	24-Hour AAQC	Arithmetic Mean	24-Hour Maximum	24-Hour Minimum	Number of Samples
Arsenic	$\mu g/m^3$	0.3	0.0014	0.0043	0.0003	54
Beryllium	$\eta g/m^3$	10	†	0.14	n.d.	55
Cadmium	$\mu g/m^3$	2	0.0016	0.091	n.d.	2840
Chromium (total)	$\mu g/m^3$	1.5	0.006	0.140	n.d.	2838
Lead	$\mu g/m^3$	5	0.040	0.340	n.d.	3181
Manganese	$\mu g/m^3$	2.5	0.072	1.35	n.d.	2841
Nickel	$\mu g/m^3$	2	0.004	0.35	n.d.	2839
Benzene	$\mu g/m^3$	*	2.64	11.65	n.d.	440
1,3-Butadiene	$\mu g/m^3$	*	0.19	1.38	n.d.	441
Carbon tetrachloride	$\mu g/m^3$	600	0.74	8.50	n.d.	413
Chloroform	$\mu g/m^3$	500	0.20	1.90	n.d.	412
1,4-Dichlorobenzene	$\mu g/m^3$	*	0.89	14.60	n.d.	408
1,2-Dichloroethane	$\mu g/m^3$	400	0.08	2.27	n.d.	413
Ethylene dibromide	$\mu g/m^3$	3	†	0.50	n.d.	412
Formaldehyde	$\mu g/m^3$	*	3.70	25.06	0.36	146
Methylene chloride	$\mu g/m^3$	1765	1.84	44.40	n.d.	386
Perchloroethylene	$\mu g/m^3$	4000	0.73	5.60	n.d.	412
Trichloroethylene	$\mu g/m^3$	28000	0.33	4.89	n.d.	413
Benzo(a)pyrene	$\eta g/m^3$	1.1** 0.3**	0.51	15.29	n.d.	495
Vinyl chloride	$\mu g/m^3$	1	†	0.62	n.d	412
Total PAH	$\eta g/m^3$	*	23.22	225.8	0.85	337
Chlorobenzenes	$\eta g/m^3$	*	1.92	15.72	n.d.	137
Chlorophenols	$\eta g/m^3$	*	2.36	12.18	n.d.	77
Polychlorinated biphenyls	$\eta g/m^3$	150	0.41	3.30	n.d.	137
Total Dioxins & Furans	pgTEQ /m^3	5††	0.228	1.732	0.012	106

Notes: μg = microgram (10^{-6} g); ηg = nanogram (10^{-9} g); pg = picogram (10^{-12} g); m^3 = cubic metres; n.d. = not detected

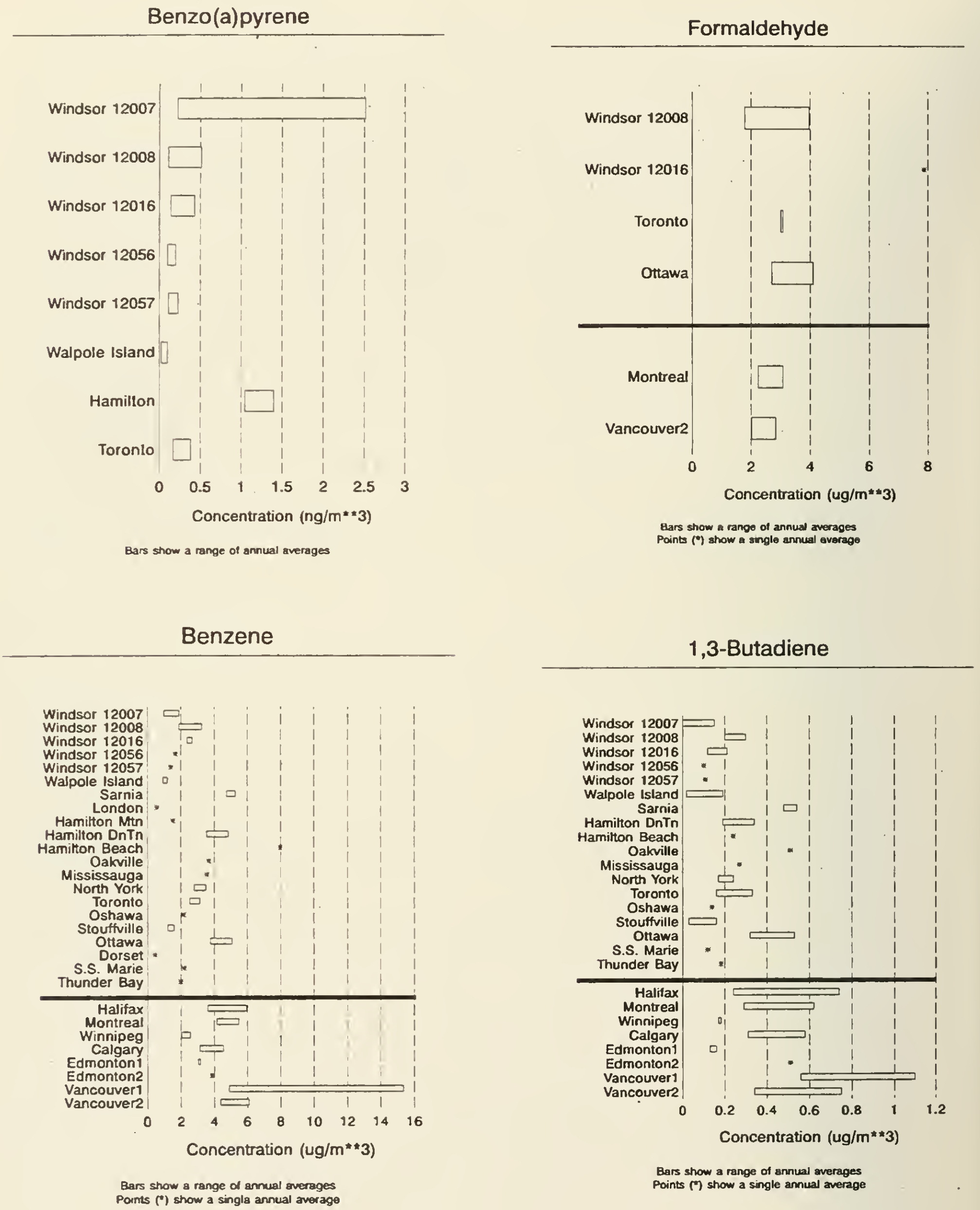
* Ambient Air Quality Criterion (AAQC) either unavailable or under development

** 24 h AAQC is 1.1 $\eta g/m^3$ for a single source. The annual value is 0.3 $\eta g/m^3$.

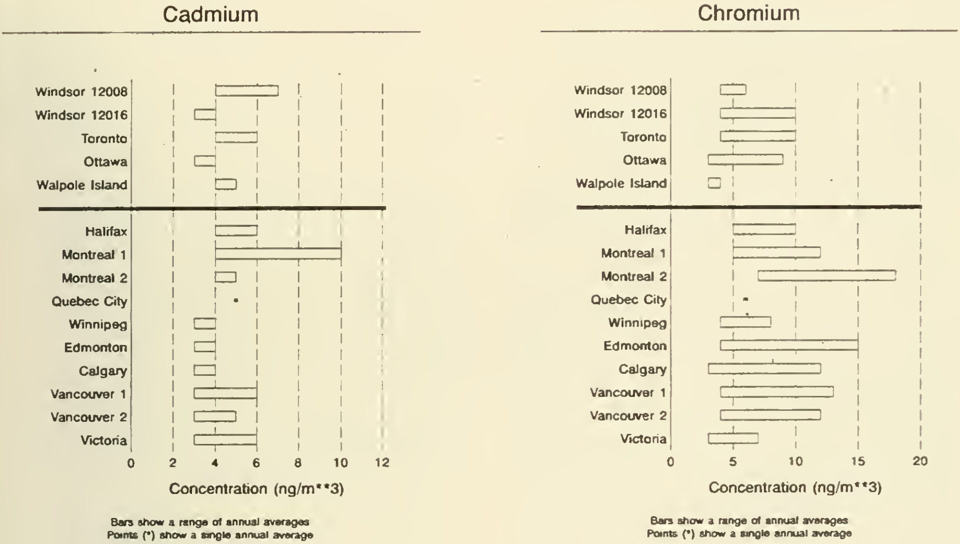
† Substance detected in less than 20% of the samples and therefore no arithmetic mean is calculated

†† Interim AAQC calculated using international Toxicity Equivalents Factors (TEQ)

Figure 3.2.2: Comparison of Windsor ambient air toxics levels with other Ontario and Canadian communities



igure 3.2.2: Comparison of Windsor ambient air toxics levels with other Ontario and Canadian communities (Cont'd.)



3.3 TAGA 6000 Survey

The Ministry's two mobile TAGA 6000 (Trace Atmospheric Gas Analyzer) units were deployed in the Windsor area as part of the Windsor Study. The TAGAs have monitoring capabilities unattainable by conventional sampling and analysis techniques. They are mass spectrometers, with the capability of instantaneously detecting and quantifying ultra trace levels of organic compounds.

Pollutant "hot spots" can be investigated by plotting pollutant levels while the TAGA is in motion and tracking plumes back to the source; odours can be chemically characterized and one can determine whether airborne toxics in the vicinity of emission sources are present at levels of concern to human health. For the Windsor Study, a specially developed analyzer was mounted in the mobile TAGA units for measurements of vapour-phase mercury at various locations. Mercury is one of the pollutants emitted by the Greater Detroit Resource Recovery Authority incinerator.

During July and August of 1990, a TAGA reconnaissance survey was conducted mainly along the Detroit River to determine if the GDRRA incinerator's emissions were impacting on Windsor. Mercury and hydrogen chloride gas were the primary target substances. Some sampling for organic compounds was also conducted in the vicinity of the Ford casting plant.

During the Windsor Study, four surveys were conducted in the Windsor area by the TAGA units (in August 1991, September 1991, July-August 1992 and October 1992). The primary purpose of these surveys was to determine if there were any air toxics "hot spots", where Ministry air quality standards were exceeded. Air samples were taken within the vicinity of a number of industrial sources, in the downtown core and in several residential areas, including west Windsor. Air samples were analyzed for various volatile organic compounds, hydrogen chloride and hydrogen fluoride gases, and mercury vapour (not all of these pollutants were measured in every one of the surveys). Samples were scanned also for hundreds of organic compounds not routinely monitored by the ambient air monitoring network.

Details of the TAGA surveys can be found in the report **Windsor Air Quality Study: TAGA 6000 Survey Results**.

The main results can be summarized as follows:

- Measured pollutants generally were detected only in the immediate vicinity of suspected industrial sources. Concentrations decreased quickly within a few hundred metres from the sources. Odours were also often present near industrial sources and were associated with different chemicals at different sources (e.g., triethylamine for the Ford casting plant, butyl cellosolve for the Chrysler minivan plant, and ethanol for the Hiram-Walker Distillery).

- The concentrations for most substances never approached the current Ministry point of impingement (POI) standards; even for samples taken close to industrial sources. In fact, half-hour average concentrations measured were typically two or three orders of magnitude lower than the POI standards for the target compounds surveyed. These results apply to samples collected in west Windsor as well as other locations in the airshed.

- Elevated hydrogen fluoride and hydrogen chloride concentrations, in excess of the half-hour POI air quality standards (4.3 and 100 $\mu g/m^3$, respectively), were frequently encountered and a detectable pollutant plume persisted as far as two kilometres downwind from the Ford Essex Aluminum Plant. Control measures are currently being put in place to reduce emissions from this facility.

- On several occasions, attempts were made to monitor the impact of Detroit sources, e.g., the impact of Zug Island industries on west Windsor or the GDRRA incinerator on downwind areas of Windsor. Such impacts were difficult to detect, which was partly due to unfavourable wind directions during survey periods. The TAGA could take up a monitoring position downwind of these sources only infrequently.

- Monitoring results for mercury, one of the compounds of concern from the Detroit incinerator, displayed a local "hot spot" in the vicinity of the now-abandoned Dominion Forge building, with half-hour average mercury concentrations ranging from about 0.001 to as high as 0.13 $\mu g/m^3$ were being measured. While this value is well above the concentrations measured elsewhere in Windsor it is still much lower than the Ministry one-half hour POI standard of 5 $\mu g/m^3$.

3.4 Personal Exposure Survey

For the Windsor Air Quality Study, specific personal exposure assessment measurement campaigns were conducted during the summer of 1991, the winter/spring of 1992 and the summer of 1992, to measure the concentrations of contaminants in the air that a person might breath during the course of daily activities.

These studies examined the personal and general air quality of a variety of microenvironments including different homes, offices, motels, hotels, vehicles, garages and a variety of communal places such as several bingo halls, a cafeteria, a retirement home, a swimming pool and a gymnasium - places where people actually spend their time. Samples were also gathered during the volunteers' commute to and from work.

The majority of the volunteers were with the government, academia or other environmental agencies; not from professions which inherently have employees spending considerably large portions of time outdoors (as an example, construction and agricultural workers).

Airborne concentrations of 56 carbonyl and other volatile organic compounds (VOCs) and 8 selected airborne trace metals were measured. All samples were either acquired within the volunteers' "breathing zone" or at a height of 1.5 metres in their microenvironments. Throughout the study, concurrent outdoor samples were also collected at the volunteers' homes and, if possible, at their offices.

For each volunteer, a 24-hour "snapshot" personal air quality profile was compiled. Based on this and their time activity diary for the same 24 hours, an exposure profile was computed.

Exposure is defined as the *product* of the *time* a person is in contact with a particular pollutant (or class of pollutants) and the *concentration* of the(se) pollutant(s) in the air that they breathe.

The results, while not extensive, do provide useful human exposure information. Details are reported in **Windsor Air Quality Study: Personal Exposure Survey Results.**

- During the summer study, 14 volunteers were involved and they spent approximately 20% of their time outdoors whereas during the winter/spring study, 17 volunteers participated in the study spent 8% of their time outdoors. Figure 3.4.1 is a composite time-budget analysis of all the volunteers for the two campaigns. "In" and "Out" in the figure refer to "indoors" and "outdoors", respectively.

- Figure 3.4.2 summarizes the relative VOC concentrations the volunteers were exposed to outdoors and in the various indoor and commuting microenvironments. Both concentrations determined from the indoor and commuting samples were considerably higher than those determined from the outdoor samples. The average commuting time was less than one hour and the majority used a car. Similar concentrations were measured in the home and the office. All 43 offices were non-smoking whereas 22 of the 36 homes were "smoke-free".

Figure 3.4.1 Time budget profile of the Windsor volunteers

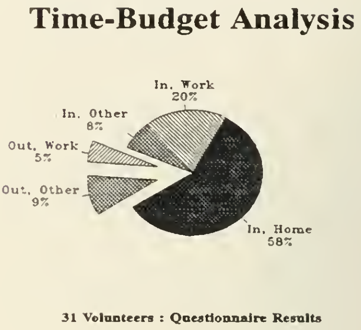
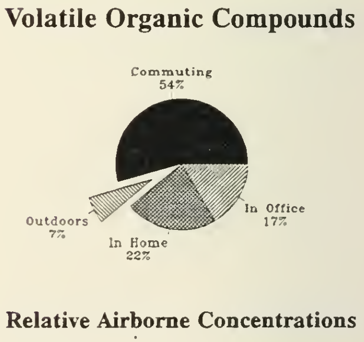


Figure 3.4.2 Relative airborne volatile organic compound concentrations in various Windsor microenvironments



- Due to the higher indoor airborne VOC concentrations and the longer times spent in the indoor microenvironments, almost 90% of the volunteers' daily exposure (concentration x time) originated from indoors. Table 3.4.1 shows the composite VOC exposure profile for all 31 volunteers. Only 3% of a person's daily exposure originates from the outdoors. Although less time is spent on commuting than outdoors (less than one hour versus ≈ three hours), higher VOC concentrations are experienced during commuting, resulting in 7% of a person's daily exposure.

- Exposure profiles to 17 carbonyl compounds (e.g., formaldehyde, acetaldehyde, acrolein, etc.) and eight airborne trace metals (e.g., manganese and lead, etc.) are also shown in Table 3.4.1. The volunteers' daily exposure to the outdoor airborne contaminants was only 3% of their total daily exposure for carbonyls and 22% for the trace metals.

- For the airborne trace metals, comparable or slightly higher concentration levels were measured in the outdoor samples when compared to those acquired indoors.

- The air quality was determined to be relatively poor in bingo halls, in new office buildings, in the car, and in garages. The presence of environmental tobacco smoke (ETS) was noted in many places - particularly in bingo halls.

- During the summer of '92, a special monitoring program and analytical method was developed for hexavalent chromium (Cr(VI)) and from the limited number of samples collected, the Cr(VI) concentration levels were found to be in the range of 0.5 to 6.0 ng/m^3 for outdoor air and 1.0 to 1.5 ng/m^3 for indoor air, respectively.

- Although many more airborne contaminants were detected in the samples collected during this Study component, Table 3.4.2 gives a summary for five of the higher risk pollutants.

- For VOCs and carbonyls, the effects of sources in the home, office and other confined or enclosed microenvironments dominate over outdoor sources such as industry and the automobile with respect to human exposure. This important fact is in agreement with the findings of other studies of personal exposure; notably the extensive TEAM (Total Exposure Assessment Methodology) studies in the United States.

Table 3.4.1 Relative exposures of Windsor volunteers to selected pollutants in various microenvironments

Compound Class	Indoors: Home	Indoors: Office	Outdoors	Commute
VOCs	≈70%	≈20%	≈3%	≈7%
Carbonyls	≈83%	≈15%	≈3%	nd
Trace Metals	≈60%	≈18%	≈22%	nd

nd: not done ≈ approximately

Table 3.4.2 Pollutant concentrations in various Windsor microenvironments

Contaminant	Outdoors		Indoors at Home		Indoors at the Office		Commuting	
	# of Smpls	Arith mean*	# of Smpls	Arith mean*	# of Smpls	Arith mean*	# of Smpls	Arith mean*
Benzene [1]	112	2.7	59	3.1	43	3.2	59	15.7
1,3-Butadiene [1]	112	na	59	0.5	43	na	59	1.1
Formaldehyde [2]	49	3.3	36	31.2	18	17.6	na	na
Cadmium [3]	49	1.3	37	0.7	17	0.8	na	na
Chromium (VI) [3]	16	2.0	3	1.2	na	na	na	na

[1] Volatile Organic Compounds - Concentration Units are $\mu g/m^3$ (micrograms per cubic metre)

[2] Carbonyls - Concentration Units are $\mu g/m^3$

[3] Trace Metals - Concentration Units are ng/m^3 (nanograms per cubic metre)

*Arithmetic means were only computed if the compound was detected in more than 20% of the collected samples. One-half of the appropriate method detection limits were substituted for the non-detects for this calculation. Smpls = Samples; na = not available/applicable.

3.5 *Soil and Garden Produce Survey*

Emissions to the atmosphere can have an impact on exposure pathways other than inhalation because some toxic substances, e.g., metals and semi-volatile organic compounds, are deposited to the earth's surface by precipitation (wet deposition) and various dry deposition processes (absorption of gases by water bodies, soils and vegetation, gravitational settling of dust, etc.). These contaminants enter the food and drinking water pathways and can be ingested. The impact of an emitting source can be quite localized, or can extend over a large area depending on the nature of the pollutants emitted.

As part of the Windsor Air Quality Study, soil and garden produce samples collected in the Windsor area in 1989 and 1990 were analyzed for various trace metals and organic compounds. Soil samples taken were limited to the top five centimetres, that is, soil which might be ingested by children at play. Locally grown garden produce samples were analyzed to supply information for the exposure assessment analyses of this Study. Not all samples were analyzed for the entire compound list targeted for primary investigation (Table 1.2.1).

A detailed presentation of the soil and vegetation results can be found in the companion report **Windsor Air Quality Study: Soil and Garden Produce Survey Results**. The data from this survey provided input to the exposure assessments carried out in the Health Effects Assessment presented in Section 3.7.

The surface soil samples had detectable concentrations for most trace metals. Results for Windsor and rural Essex County locations are summarized in Table 3.5.1. This table shows the range of values found for different metals, the concentrations being expressed in parts per million by weight (ppm-w), which is also equivalent to microgram of metal per gram of soil.

- Similar means and ranges of concentration for most metals were observed at Windsor (urban) and Essex County (rural) locations. Exceptions were cadmium and mercury, which tended to have higher concentrations at Windsor locations.

- The concentrations of all trace metals in soil samples collected at Windsor urban locations were at or below the Ministry's urban Upper Limit of Normal (ULN) guideline concentrations. The trace metal concentrations in soil from all rural samples had concentrations at or below the rural ULN guidelines.

- Polynuclear aromatic hydrocarbons were consistently detected in soil samples collected at urban locations, but not at rural locations. Of the 16 different PAHs analyzed in the soil samples, a high proportion were below the method detection limits. This is in line with levels found in other Ontario communities. For example, for benzo(a)pyrene, 76% of the measurements were less than 0.20 ppm-w (the highest value found in this survey was 0.91 ppm-w).

- The polychlorinated biphenyls (PCBs) and chlorinated aromatics results for the soil samples were less than the detection limits of 0.02 ppm-w and 0.001-0.002 ppm-w, respectively.

- Dioxins and furans were detected in many of the surface soil samples, but there was no clear difference between the results for the urban Windsor and rural Essex County sites.

- For locally grown produce samples, chlorinated aromatics concentrations were below the analytical detection limit, namely 0.001-0.002 ppm-w. PCBs were also less than the detection limit of 0.02 ppm-w of vegetation. Dioxins and furans were only occasionally detected, with no clear indication of elevated levels in Windsor as compared to surrounding rural areas.

Table 3.5.1: Summary of metal concentrations (ppm-w) in Windsor and rural Essex County surface soil

Metal	City of Windsor (n=36)			Essex County (n=54)		
	Maximum	Minimum	Arithmetic Mean	Maximum	Minimum	Arithmetic Mean
Arsenic	16.7	4.1	7.2	7.2	4.8	5.8
Beryllium	0.8	0.3	0.7	1.0	0.6	0.8
Cadmium	1.7	0.41	0.79	1.1	0.06	0.49
Chromium (total)	33	20	25	29	19	23
Lead	128	23	59	130	17	44
Manganese	413	160	244	317	167	223
Mercury	0.20	0.02	0.08	0.07	0.01	0.04
Nickel	24	14	21	27	19	23
Vanadium	43	28	35	48	34	39

3.6 *Mathematical Modelling and Source Apportionment*

A state-of-the-art urban dispersion model, developed as part of the Ministry's proposed updating of its Environmental Protection Act's Regulation 346 models, was used to (1) determine the relative contributions of various source sectors to ambient concentrations for 21 compounds; (2) describe the spatial distribution of the air concentrations of these compounds across the Windsor area; (3) provide a check on the adequacy of the emissions inventories.

For a complete discussion of the modelling results, see the report **Windsor Air Quality Study: Mathematical Modelling and Source Apportionment.**

Summaries of the source apportionment of air concentrations averaged over the Windsor area are given in Tables 3.6.1 and 3.6.2 for the Canadian (Windsor and vicinity) sources and the U.S. (Detroit and vicinity) sources, respectively. Only results pertaining to compounds identified to contribute to the higher cancer risks and other chronic impacts due to inhalation are highlighted here.

Source Apportionment

The modelled contribution to average Windsor air concentrations has been found to be as follows:

- For carbon tetrachloride, long range transport is a dominant source of the observed air concentrations.
- Photochemistry, along with long range transport, accounts for 60 to 80 % of the modelled formaldehyde air concentrations.
- Contributions to modelled Windsor air concentrations from sources in the Detroit area were about 58% for cadmium, 65% for chromium, 67% for B(a)P and benzene, and 76% for 1,3-butadiene.
- Area sources, particularly mobile emissions, were the dominant source sector for benzene (84%), 1,3-butadiene (96%) and B(a)P (99%).
- The largest contributors to the modelled chromium air concentrations are the steel industry in Detroit (50%) and the motor vehicle manufacturing sector in Windsor (16%).
- For cadmium, a significant modelled contribution of about 35% is due to road dust from Windsor and Detroit. The motor vehicle manufacturing in Windsor and the steel industry in Detroit contribute, respectively, 27% and 13% to the modelled contributions to the Windsor airshed.

Spatial Concentration Profiles

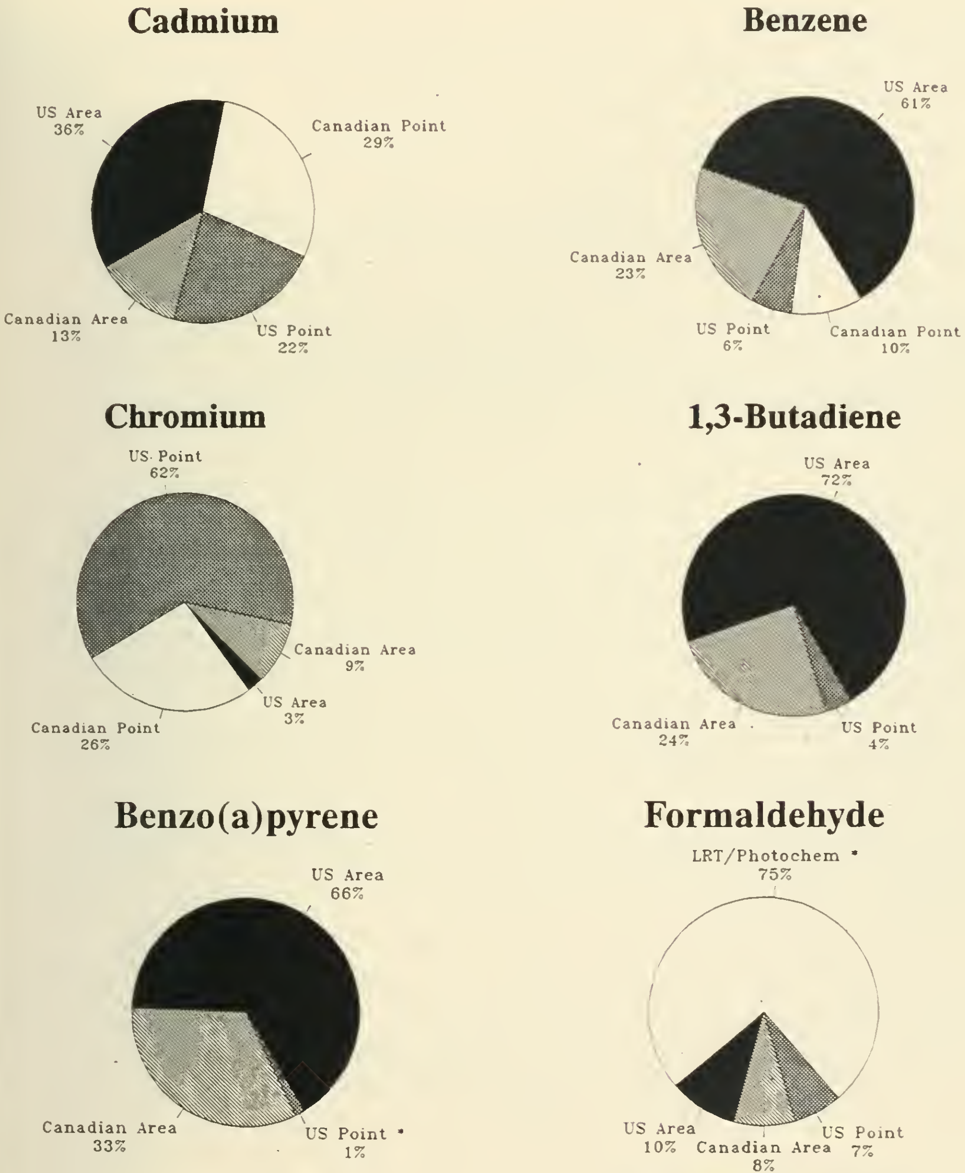
In the Windsor area:

- Chromium and cadmium have higher modelled air concentrations over the north-central part of Windsor.
- 1,3-Butadiene and B(a)P were dominated by emissions from area sources and showed similar patterns of air concentrations. The

highest values were in the northwest part of Windsor with a gradual reduction in concentrations toward the south-east.

- For benzene, the contribution due to Windsor industrial sources added to that due to the area source produced a maximum modelled impact in north-central Windsor.
- Formaldehyde also showed the highest concentration in the northwest but the relatively large background concentration result in a much less pronounced concentration drop-off to the southeast.
- Canadian point source contribution relative to that of the US was found to be higher at receptors near the maximum modelled concentrations than the average greater Windsor area.

Figure 3.6.1 : Source apportionment in the Windsor area - US vs. Canadian Source Contributions



* <1%

* LRT - Long Range Transport / Photochemistry

Table 3.6.1: Summary of percentage contribution to ground level concentrations in Windsor due to Ontario sources from Windsor and vicinity (refer also to Table 3.6.2)

Pollutant	Motor Vehicle Manufacturing	Steel Mills Iron Foundries	Mobile Sources	Utilities and Other Fuel Combustion	Other Point Sources	Other Area Sources	Total %
Arsenic	15	-	-	-	1	38	54
Beryllium	-	-	-	-	12	-	12
Cadmium	27	-	-	-	2	13	42
Chromium (total)	16	1	2	7	9	-	35
Lead	11	1	33	-	5	2	52
Nickel	19	1	6	21	5	-	52
Mercury*	-	-	-	-	3	1	4
Benzene	8	-	17	3	2	3	33
1,3-Butadiene	-	-	16	-	-	8	24
Formaldehyde*	-	-	7	1	-	-	8
Carbon tetrachloride*	-	-	-	-	-	-	0
Vinyl chloride	-	-	-	-	-	1	1
Benzo (a) pyrene	-	-	12	21	-	-	33
Polychlorinated biphenyls	-	-	-	-	-	-	0
Dioxins	-	-	-	24	-	2	26
Furans	-	-	-	24	-	2	26
Acrylonitrile	45	-	-	-	-	-	45
Perchloroethylene	1	-	-	-	17	38	56
Trichloroethylene	-	-	-	-	-	5	5

* These compounds have a large long-range transport and/or photochemical contribution to the ambient air concentrations in Windsor.

Table 3.6.2 Summary of percentage contribution to ground level concentrations in Windsor due to Michigan sources from Detroit area (refer also to Table 3.6.1).

Pollutant	Motor Vehicle Manufacturing	Steel Mills Coke Ovens	Mobile Sources	Utilities and Other Fuel Combustion	Other Point Sources	Other Area Sources	Total %
Arsenic	11	10	-	2	19	4	46
Beryllium	37	-	-	-	51	-	88
Cadmium	3	13	-	-	6	36	58
Chromium (total)	1	50	-	3	10	1	65
Lead	3	11	2	-	1	31	48
Nickel	11	11	-	11	15	-	48
Mercury*	-	-	-	-	13	3	16
Benzene	1	2	31	6	3	24	67
1,3-Butadiene	1	-	45	-	3	27	76
Formaldehyde*	-	-	7	-	7	3	17
Carbon tetrachloride*	-	-	-	-	-	-	0
Vinyl chloride	-	-	-	-	-	99	99
Benzo (a) pyrene	-	-	44	22	1	-	67
Polychlorinated biphenyls	89	-	-	-	11	-	100
Dioxins	-	-	-	-	74	-	74
Furans	-	-	-	-	74	-	74
Acrylonitrile	-	45	-	-	10	-	55
Perchloroethylene	2	1	-	-	-	41	44
Trichloroethylene	27	4	-	-	11	53	95

* These compounds have a large long-range transport and/or photochemical contribution to the ambient air concentrations in Windsor.

3.7 Health Effects Assessment

A risk analysis was conducted to evaluate the chronic health implications associated with the Study's findings.

The objectives of this Study component were to:

- describe the risks due to air toxics in Windsor;
- to identify candidate substances for exposure reduction; and
- to place the inhalation risks from outdoor air in perspective with other risks.

The risk analysis for each compound contains three components:

1) Identification of the range of risks associated with inhalation based on values established by key agencies such as the U.S. Environmental Protection Agency, the California Department of Health Services, and the World Health Organization.

2) Determination of exposure scenarios based on the mean and 90th percentile concentrations of measured outdoor air pollutants, reported in the **Windsor Air Quality Study: Ambient Air Monitoring Activities**; and the measured concentrations of pollutants in various microenvironments, reported in the **Windsor Air Quality Study: Personal Exposure Survey Results**.

3) Comparison with guidelines for outdoor concentration limits and indoor occupational limits (perspective purposes only), set by a number of regulatory agencies.

The approach used overcomes some limitations, such as not having Ontario standards for all compounds. It also provides an evaluation of the risks associated with different exposure scenarios and provides a range of risks which reflect the differences in cancer potency factors put forward by key international agencies.

Three inhalation scenarios were considered, namely, outdoor air quality (100% outdoor exposure), typical outdoor exposures (3 hours) and typical personal exposures. Both carcinogenic and non-carcinogenic health risks were addressed for these three situations.

To place the inhalation risks in perspective, other exposures were also evaluated. These included ingestion, dermal exposures, smoking, and a comparison to outdoor air in other urban centres.

The risk analysis approach which was used is widely accepted in North America and Europe. In general, the approach is very conservative and tends to overestimate risks, particularly at the higher end of the range.

Direct health effects from low level, long-term exposure to air toxics are difficult to measure because of the many compounding variables such as lifestyle, diet, etc. Estimation of cancer risks is the most reasonable scientific approach at the present time for bridging this knowledge gap. The estimates are very conservative and probabilistic in nature. Therefore while these estimates are not absolute, they do provide a basis for prudent decision making and for comparison of risks.

Generally, risks below the 1×10^{-5} level (i.e., an incremental cancer case of one out of 100,000 people) are deemed to be negligible by most regulatory agencies. However, the acceptability of risk is always considered to be a decision that the affected population needs to make.

The 1 x 10^{-5} level of risk has been used as a potential guide for identifying substances of potential concern in the Windsor area.

The results of the risk analysis are summarized in the report **Windsor Air Quality Study: Health Effects Assessment.**

Comparison to Ambient Air Quality Criteria

Ontario's existing ambient air quality criteria and standards were used for a first-cut assessment of whether exposures of residents living in a specific airshed, such as Windsor, are unacceptable.

In Table 3.2.1 of Section 3.2, ambient concentrations of the target compounds in the Windsor Air Quality Study were compared with Ministry air quality criteria. The comparison showed that, both mean and maximum measured airshed concentrations were usually considerably lower than the Ministry criteria. The one exception was B(a)P.

Inhalation Cancer Risks

Risk estimates shown in Figure 3.7.1 and 3.7.2, were developed from exposures based on concentrations of pollutants measured in the Windsor area and the range of potency factors proposed by leading agencies. The **low end** of the range of risks corresponds to the mean measured concentration and the least conservative potency factor; the **high end** of the range corresponds to the 90th percentile of the measured concentrations and the most conservative potency factor. The high end of the range of risks thus represents the most conservative estimate.

Chemicals of Concern

To identify the chemicals of concern, the inhalation cancer risks can be interpreted in two ways.

In the most conservative approach, all substances for which the **high end** of the range of risks is elevated above 1 x 10^{-5} risk level are identified. These substances in approximately decreasing order of risk are:

- Outdoor air quality: chromium(VI), benzene, 1,3-butadiene, polynuclear aromatic hydrocarbons (PAHs which include B(a)P), carbon tetrachloride, cadmium, acetaldehyde, perchloroethylene, and 1,4-dichlorobenzene[1], (see Figure 3.7.1).
- Typical outdoor exposure: chromium(VI), benzene, and 1,3-butadiene.
- Typical personal exposures for non-smokers: 1,3-butadiene, benzene, chromium(VI), chloroform, carbon tetrachloride, PAHs, acetaldehyde, perchloroethylene, ethylene dichloride, formaldehyde, methylene chloride, cadmium, and 1,4-dichlorobenzene[1] (see Figure 3.7.2).

[1] Listed last because of the provisional nature of the risk estimates for this substance. Classification of 1,4-dichlorobenzene as a carcinogen has recently been removed from the Integrated Risk Information System (IRIS) database by the US EPA, hence the calculated cancer risks may bear no significance.

The second approach, for identifying substances of greatest risk, targets only those substances, where a major portion of the range is elevated above the 1 x 10^{-5} risk level. This approach is probably more reasonable since conservative assumptions are already built into both the exposure measurements and the potency factors proposed by regulatory agencies. Based on this interpretation, the substances of concern include:

- Outdoor air quality: chromium(VI), benzene, 1,3-butadiene (see Figure 3.7.1).
- Typical outdoor exposure: No substance identified.
- Typical personal exposures for non-smokers: 1,3-butadiene, benzene, chromium(VI), chloroform, carbon tetrachloride, PAHs, acetaldehyde, perchloroethylene, ethylene dichloride, formaldehyde, methylene chloride, cadmium, and 1,4-dichlorobenzene (see Figure 3.7.2).

Figure 3.7.1 : RANGE of RISKS for INDIVIDUAL POLLUTANTS OUTDOOR AIR QUALITY

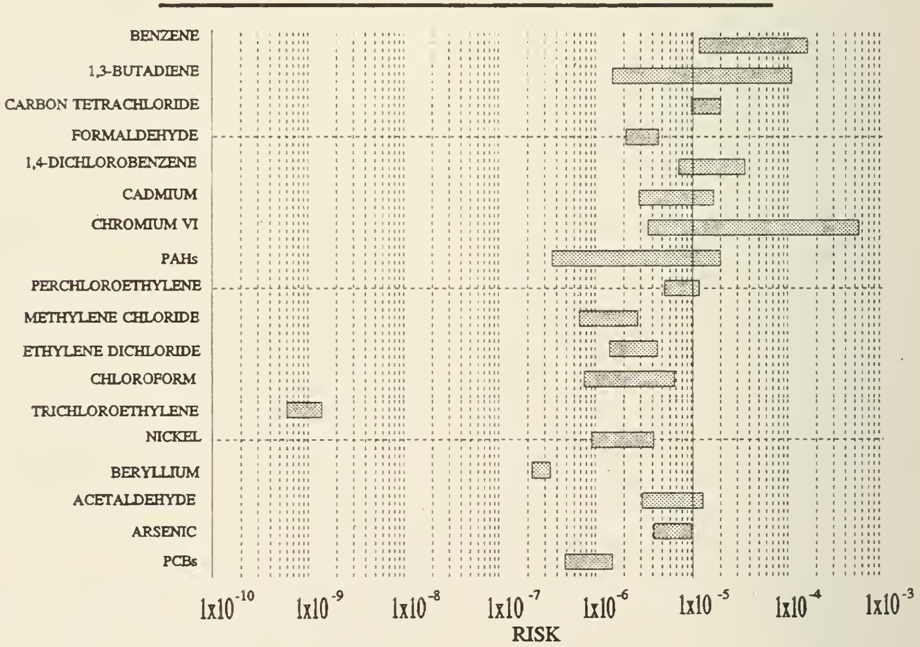
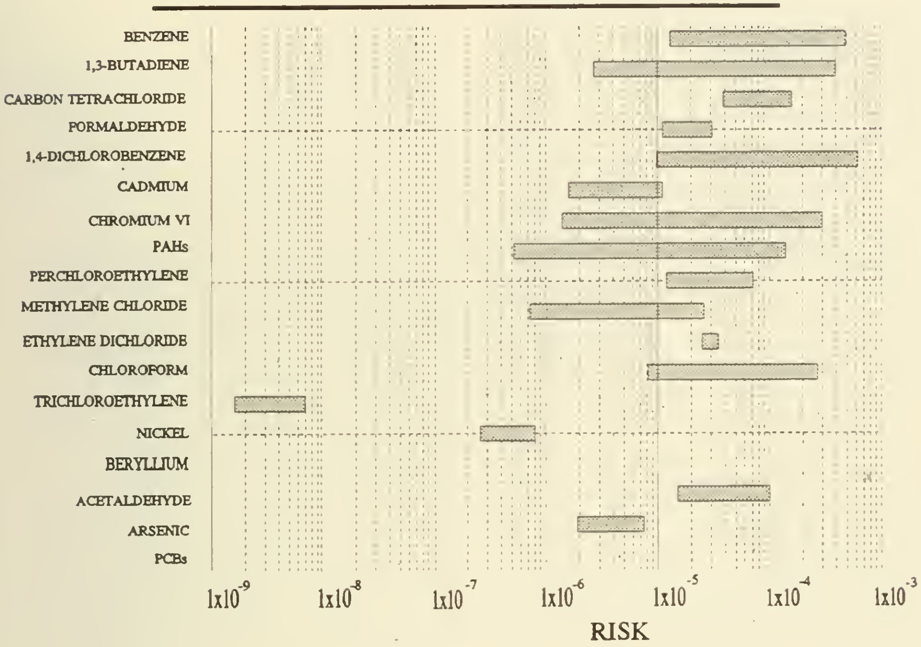


Figure 3.7.2 : RANGE of RISKS for INDIVIDUAL POLLUTANTS TYPICAL PERSONAL EXPOSURES or INDOOR ENVIRONMENTS



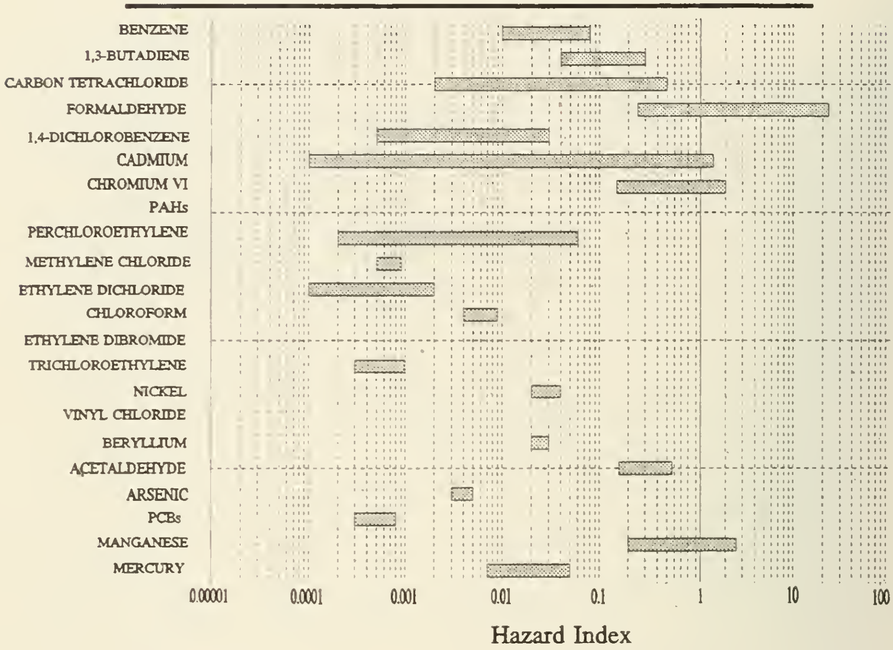
Inhalation Non-Cancer Risks

Most chronic health effects (e.g., effects on the liver, kidney) are generally associated with higher pollutant concentrations than cancer effects. To protect against such health effects, regulatory agencies have established acceptable exposure levels.

These risks were evaluated quantitatively using a hazard index, which is the ratio of the exposure concentration of a certain pollutant in the air to the acceptable exposure level. Hazard index levels greater than one indicate a possibility of long-term non-cancer effects. Based on the hazard index the following substances are of potential concern:

- Outdoor air quality: formaldehyde, chromium(VI), manganese, and cadmium, (see Figure 3.7.3).
- Typical outdoor exposure: formaldehyde.
- Typical personal exposures for non-smokers: formaldehyde, acetaldehyde, carbon tetrachloride, 1,3-butadiene, and chromium(VI).

Figure 3.7.3 : RANGE of CHRONIC HAZARD INDICES for INDIVIDUAL POLLUTANTS
OUTDOOR AIR QUALITY



Health Risks from other Routes

Humans are also exposed to chemicals through ingestion of water and food and dermal absorption through the skin.

Ingestion was identified as a major route of exposure (in terms of magnitude of intake but not contribution to health risks) for formaldehyde, cadmium, chromium(VI), dioxins and furans, and mercury. Marginally, PAHs may contribute to health risks via the ingestion route. Although the inhalation route was dominant for 1,3-butadiene, carbon tetrachloride and 1,4-dichlorobenzene, ingestion and/or skin absorption also contribute to exposure. Limited analysis indicated that the ingestion and dermal absorption pathways for benzene, cadmium, chromium, and formaldehyde are insignificant for one or all of the following reasons:

-Substance is not carcinogenic by these routes of exposure.

-Exposures by these routes is much lower than by inhalation and therefore contribution to carcinogenic risk is negligible.

-Exposures by these routes is less than the oral reference dose (RfD), which is a "guideline" set to prevent systemic non-carcinogenic effects.

Based on existing monitoring information for dioxins and furans, the sum of exposures from all routes was found to be less than 25% of the tolerable daily intake, suggesting that the possibility of long-term health effects in Windsor due to these compounds is unlikely. In the case of mercury, inhalation and ingestion exposures amount to, respectively, less than 10% and about 50%, of the applicable chronic acceptable exposure guidelines, suggesting that the possibility of long-term health risks in Windsor due to mercury is unlikely.

It should be noted, however, that in addition to the cancer and other health risks associated with pollutants, some pollutants have either or both persistent and bioaccumulation properties, which could lead to long-term contamination of the environment resulting in risks to humans and various parts of the ecosystem. Chromium (VI), PAHs, 1,4-dichlorobenzene, carbon tetrachloride, cadmium, dioxins and furans, and mercury are such substances. Because of their persistence in the atmosphere or other media of the environment and bioaccumulation in the food chain, efforts should continue to reduce the emissions of and human exposure to all of these substances to prevent possible higher exposures in the future.

Indoor, Outdoor and Typical Exposures

"Typical personal exposures", which are dominated by indoor environments (i.e., home and office), exceed exposures associated with "outdoor air quality". Commuting and tobacco smoke-affected environments result in the highest exposure levels in the "typical personal exposure" scenarios which were evaluated. The range of additive risks associated with typical personal exposures (calculated by adding the risks for each compound) is higher than the range of additive risks associated with outdoor air quality; i.e., 1.3×10^{-4} - 2.2×10^{-3} vs. 5.0×10^{-5} - 9.4×10^{-4}.

Smoking Activity

Direct intake from smoking greatly increases exposure for several substances which were targeted as toxic air pollutants in this Study. In several cases, a smoker's daily intake of benzene, 1,3-butadiene, formaldehyde, cadmium, chromium, PAHs, and dioxins and furans, greatly exceeded the intake from all other inhalation exposure scenarios.

Putting Risks in Perspective

Risks associated with typical personal exposures are generally higher than those associated with outdoor air.

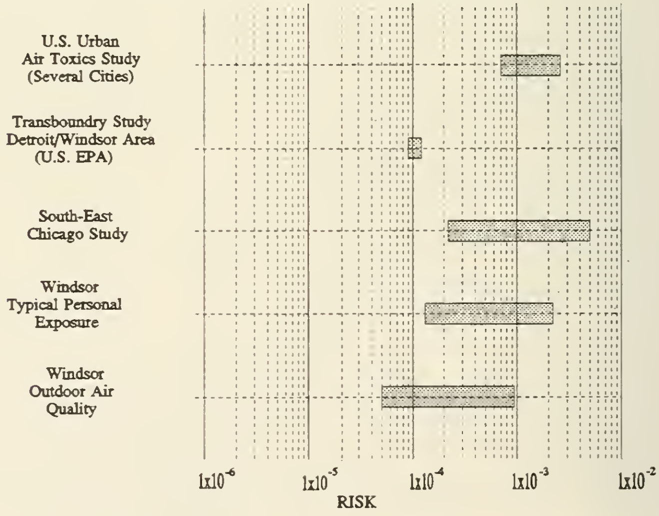
To put the risk assessments in perspective, risks associated with some familiar activities are listed below:

- Breathing outdoor air in Windsor (combined impacts of air toxics) 5×10^{-5} - 9.4×10^{-4}
- Smoker cancer risk (1 pack per day) 1×10^{-2}
- Prevailing cancer rate 3.3×10^{-1}

In addition, the carcinogenic risks associated with the combined impact of air toxics were estimated and compared to results from other urban airshed studies, e.g., South-east Chicago study (1989), the US EPA's Transboundary Study in the Detroit/Windsor Area (1990), and other US Urban Air Toxics Study (1984).

The range of additive risks from all pollutants associated with outdoor air quality in Windsor is between 5×10^{-5} and 9.4×10^{-4}. The overall range of risks from the other urban areas are between 9×10^{-5} and 5×10^{-3}, essentially overlapping with and exceeding the range of risks in Windsor (see Figure 3.7.4). No Canadian data were available for this comparison.

Figure 3.7.4 : TOTAL RISK ASSOCIATED WITH OUTDOOR AIR QUALITY in WINDSOR
A Comparison with Other Urban Areas



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